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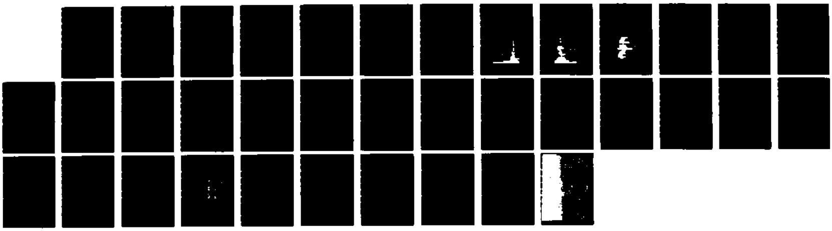

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Our research on solar flares and erupting filaments lead to the development of a formula for forecasting the eruption of quiescent filaments under the circumstance of the birth of a new active region within 30 heliographic degrees of the filament. The probability of eruption of such a quiescent filament is:

$$P = 55 + 14K_{f1} + 4K_{f2} - 18K_{f3}$$

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where K_{f1} and K_{f2} are coded values for the linear and quadratic contributions respectively of the total photospheric magnetic flux related to the filament and K_{f3} is the linear contribution of the rate of growth of the new region. The 95% confidence limit for forecasts made using this formula is ± 23%. The formula is based on the analyses of magnetograms and photographic records of 267 quiescent filaments. The development of the formula from regression analysis was supplemented by 3 seasons of trial forecasting in real time during 4 years of observing the sun with telescopes equipped with Ha filters.

Parameters that were studied and found not to be significantly correlated with the eruption of filaments were (a) distance, up to 30 heliographic degrees, between the new regions and the filaments, (b) the relative orientations of the magnetic field of the new regions and the filaments, and (c) longitudes of the new regions. Filament length was correlated with filament eruption but was found to be a factor dependent upon the total flux of the photospheric magnetic fields related to, supporting, or containing the filaments. No evidence was found in x-ray images to either confirm or negate our hypothesis that the eruption of quiescent filaments is triggered by magnetic reconnection between the new active regions and the fields adjacent to the filaments.

Other accomplishments were:

(1) publication of a review paper entitled "Preflare Conditions, Changes and Events" (Martin, 1980).

(2) co-authoring the paper "Mechanical Energy Output of the 5 September 1973 Flare" (Cheng et al., 1979). We contributed the analyses of the mechanical energy of the surge and erupting filament with this flare.

(3) publication of a research paper on the analyses of a system of flare loops with a flare on 29 July 1973. We were able to show that the orientation of the coronal magnetic fields during the flare were significantly different from the orientation of the coronal magnetic fields immediately preceding the flare (Martin, 1979).

(4) publication of a research paper on "Forecasting Flares Based on Magnetic Field Configurations" (Harvey and Martin, 1980). The magnetic field configurations that yielded the highest degree of flaring were reversed polarity regions, satellite magnetic poles around sunspots and most cases of newly emerging magnetic flux.

(5) co-authoring of a paper "Flare-Sprays" in which the subject is more clearly defined by new observations. Flare-sprays are reinterpreted as rapidly moving erupting prominences or filaments (Tandberg-Hanssen et al., 1980).

(6) publication of a paper suggesting the application of the Kopp and Pneuman flare-loop model to the whole flare instead of just to the Ha post-flare loops which it originally was proposed to explain (Svestka, et al., 1980).

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STUDIES OF SOLAR FLARES AND ERUPTING FILAMENTS

FINAL REPORT

AFOSR Grant 80-0289
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Grant 76-3068

Inclusive Period of Performance:
1 July 1976 - 30 September 1981

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TABLE OF CONTENTS

A. RESEARCH OBJECTIVES

The theme throughout our several research projects has been to better understand how and why solar flares occur. Since the energy of flares must be derived from the magnetic fields of the active regions in which flares occur, one of our goals was to seek evidence of magnetic field configurations and changes associated with flares. To date, available magnetic field data has been limited to magnetograms of the line-of-sight component only. Evidence of magnetic field changes perpendicular to the line-of-sight component can be sought indirectly from solar structures visible in Hα filtergrams. Hence another goal has been the acquisition and analyses of H images to look for structural changes in fibrils or filaments as evidence of magnetic field changes. A third goal has been to test our ability to forecast erupting filaments and associated flares using our current knowledge of the relationships of flares to magnetic field configurations, preflare mass motions in filaments, and the birth of new active regions.

B. STATUS OF THE RESEARCH PROGRAM

Our proposed studies of solar flares are now completed. All significant findings from our research has been reported at scientific meetings. To date, all of our results have also been formally published with the exception of the analyses which lead to the development of techniques for forecasting the eruption of filaments which are described in detail in the following section of this report. The results of this study will be rewritten in the appropriate format for submission to the journal, Solar Physics.

C. ACCOMPLISHMENTS DURING THE FINAL YEAR

1.0 RELATIONSHIP TO PREVIOUS WORK

During FY 1980 we found that the eruption of quiescent filaments was correlated directly with the rate of growth of new active regions within 30 heliographic degrees of the center of the filaments, and inversely correlated with the total flux of the magnetic field in the photosphere adjacent to the filaments, and the distance of the new regions from the filaments. These results were found during the study of quiescent filaments in the interval August 1978 - October 1979. During FY 1981 we performed a similar analyses of data from the interval 1 June 1973 - 30 October 1973. The earlier study included 117 quiescent filaments and the more recent study (FY 1981) included 150 filaments. The supplementary study of the additional 150 filaments had the following three purposes: (1) increasing the total sample of data to a more meaningful size for statistical analyses, (2) comparison of similar data during distinctly different phases of the solar cycle, and (3) the study of parameters not previously considered

in the previous analyses of the eruption of filaments.

2.0 CONFIRMATION OF PREVIOUS RESULTS

In analyzing the 1973 data estimates rather than measurements were made of the associated total flux of the magnetic fields surrounding the filaments. The data was divided into 5 bins according to the apparent total flux of the adjacent magnetic field. Then, as previously done for the 1978-1979 data, a graph was made showing the number of filaments that did and did not erupt as a function of the total magnetic flux. The result for the 1973 data is shown in Figure 1 in comparison with the 1978-79 data. The 1973 data show the same trends as the 1978-79 data except that a higher percentage of filaments erupted in strong magnetic fields.

In Figures 2 and 3 respectively, are the other comparisons of the 1973 data with the 1978-79 data for the rate ot growth of the new regions and the distance of the filaments from the new regions. Again the 1973 data confirms the previous results found in the 1978-79 data. The percentage of erupting filaments increases with increasing rate ot growth ot the new regions. Also, The percentage of eruptions appears to decrease slightly with distance of the new regions from the filaments although this correlation seems to be weak in both sets of of data.

To estimate the rate oт growth of the new active regions and the total magnetic flux of the magnetic fields adjacent to the filaments for the 1973 data, we used the index, area X intensity (AI) of the CaII plage of the regions, instead of magnetic flux as measured for the 1978-79 data. We employed the AI index because we found a significant correlation between AI and magnetic flux for the 1978-79 data. In Figure 4, we show the conversion from the AI index to maximum magnetic flux derived from multiple regression. The advantages of using the AI index is that it is available from Solar Geophysical Data, whereas magnetic flux would have had to be measured. A second advantage of the AI index is that it can be available in real time whereas real time measures ot magnetic flux are not readily available.

Since the trends in the 1973 data are similar to those found in the 1978-79 data, we combined the two sets for further statistical analyses of the significance of the studied parameters in relationship to the eruption of quiescent filaments. However, before proceeding with the statistical analyses, we investigated additional parameters as described below to determine if any other factors might also be related to the eruption of quiescent filaments.

3.0 ANALYSES OF ADDITIONAL PARAMETERS

3.1 Filament Length

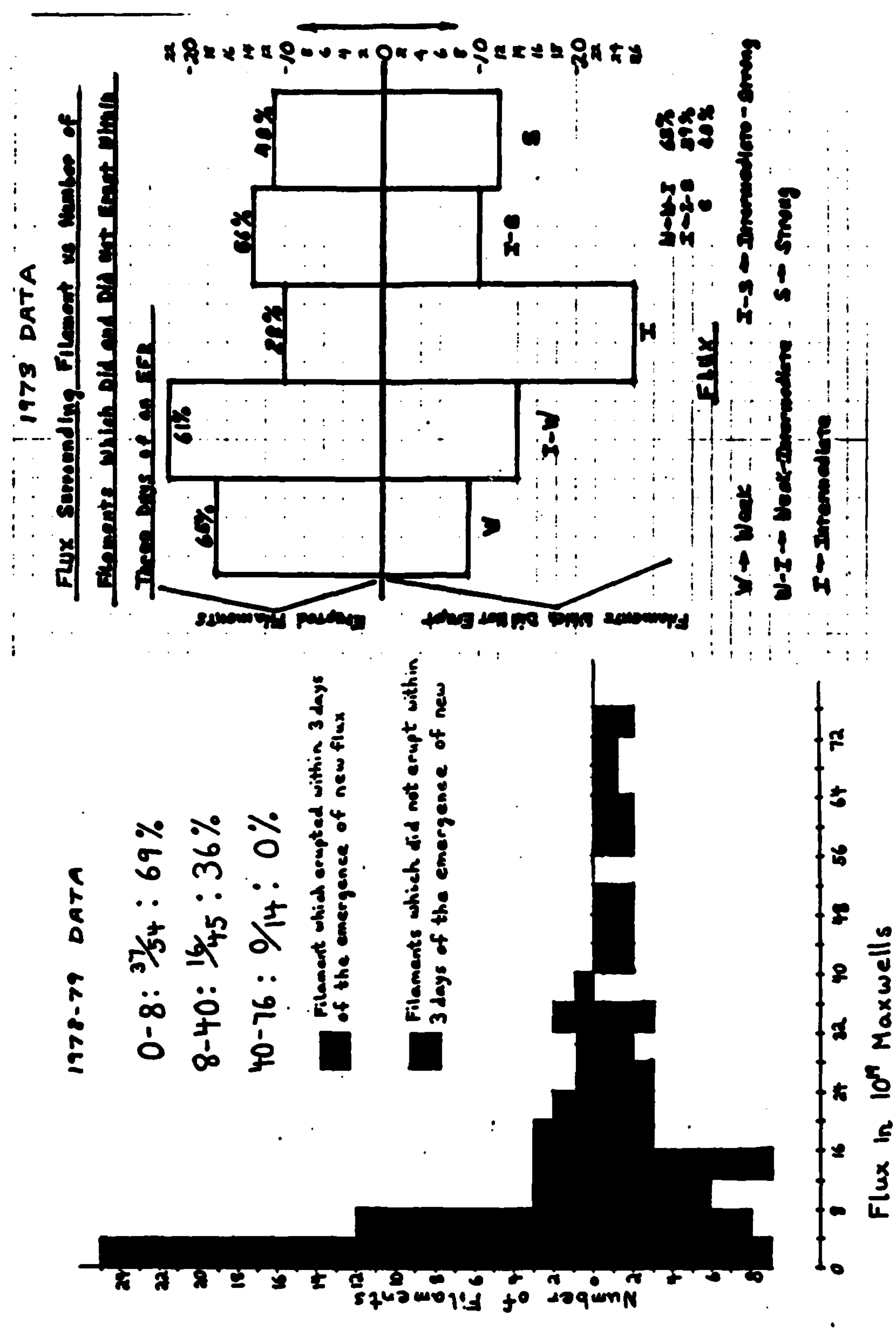
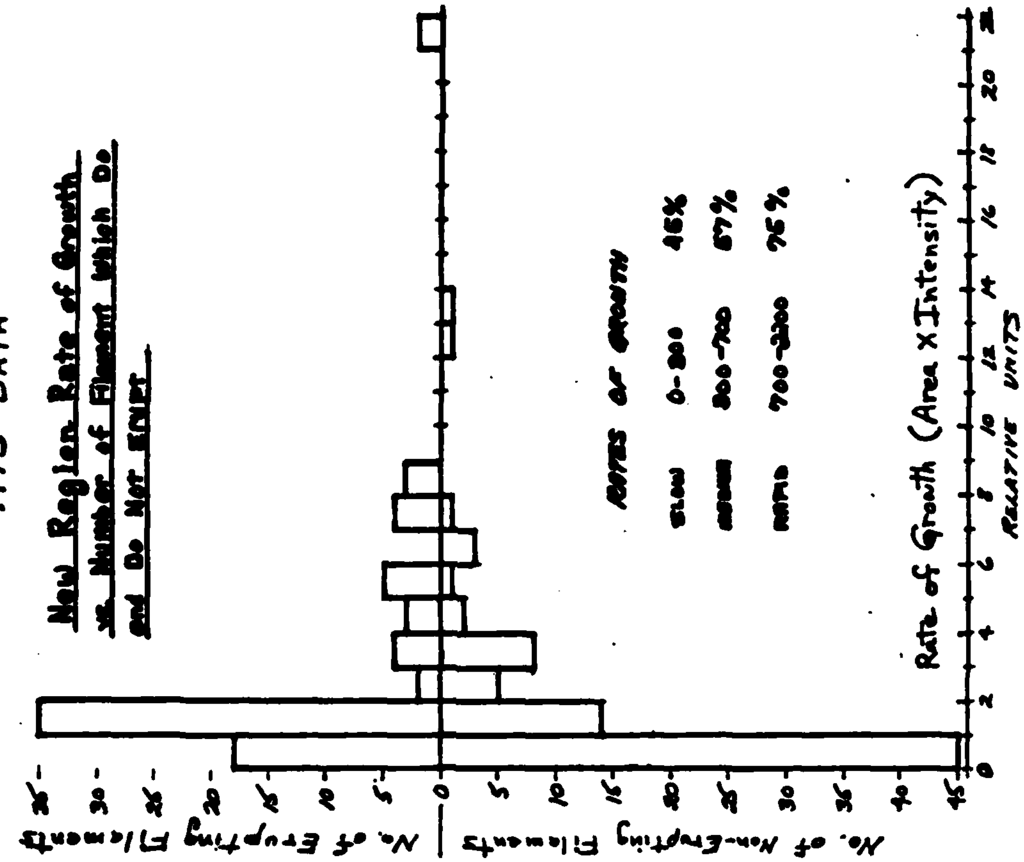
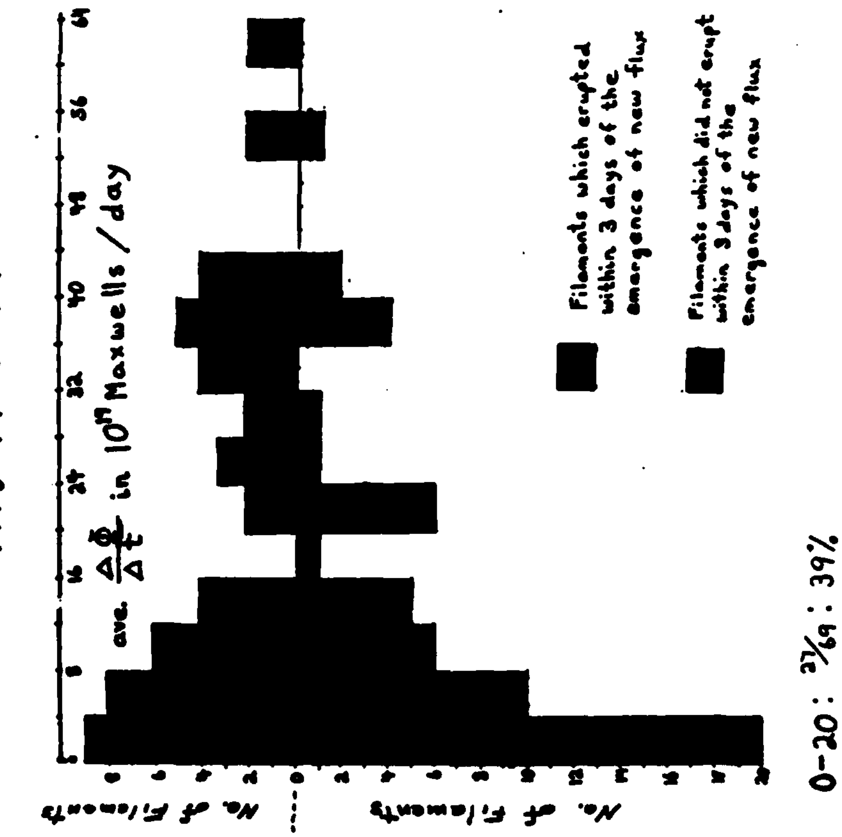

1978-79 DATA
0-8: 37/54 : 69%
8-40: 16/45 : 36%
40-76: 0/14 : 0%
Filament which erupted within 3 days of the emergence of new flux
Filaments which did not erupt within 3 days of the emergence of new
Number of Filaments
Flux in 10^{19} Maxwells
1973 DATA
Flux Surrounding Filament vs Number of Filaments Which Did and Did Not Erupt Within Three Days of an EFR
Erupted Filaments
Filaments Which Did Not Erupt
65%
61%
28%
62%
48%
W
I-W
I
I-S
S
FLUX
W → Weak
W-I → Weak-Intermediate
I → Intermediate
I-S → Intermediate-Strong
S → Strong

Figure 1



1973 DATA
New Region Rate of Growth vs. Number of Filament Which Do and Do Not Erupt
RATES OF GROWTH
SLOW 0-300 46%
MEDIUM 300-700 57%
RAPID 700-2200 75%
Rate of Growth (Area X Intensity)
RELATIVE UNITS
No. of Erupting Filaments
No. of Non-Erupting Filaments

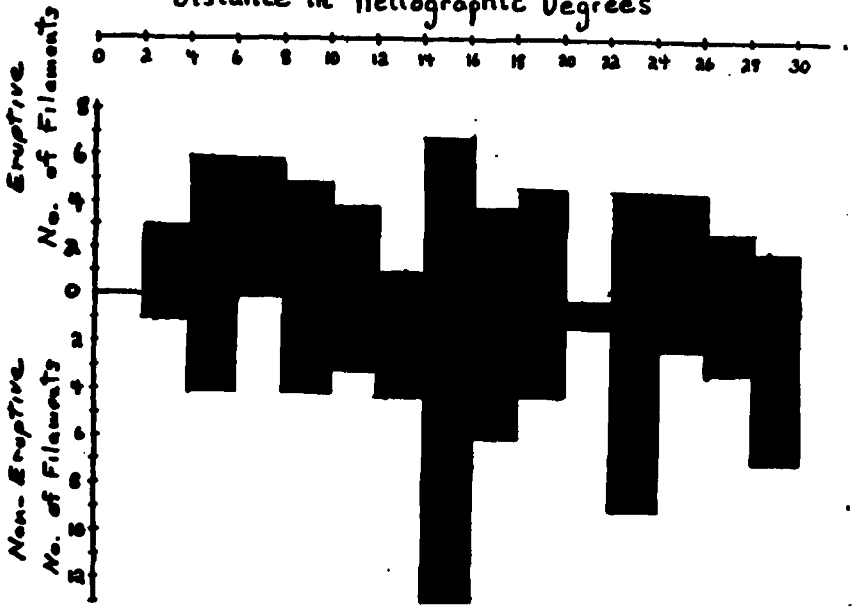


1978-79 DATA
ave. ΔΦ/Δt in 10¹¹ Maxwells / day
Filaments which erupted within 3 days of the emergence of new flux
Filaments which did not erupt within 3 days of the emergence of new flux
No. of Filaments
0-20: 27/69 : 39%
20-40: 16/28 : 57%
40-64: 10/13 : 77%

Figure 2

1978-79 DATA

Distance in Heliographic Degrees



0°-10° : 20/29 : 69%

11°-20° : 21/51 : 41%

21°-30° : 15/37 : 41%

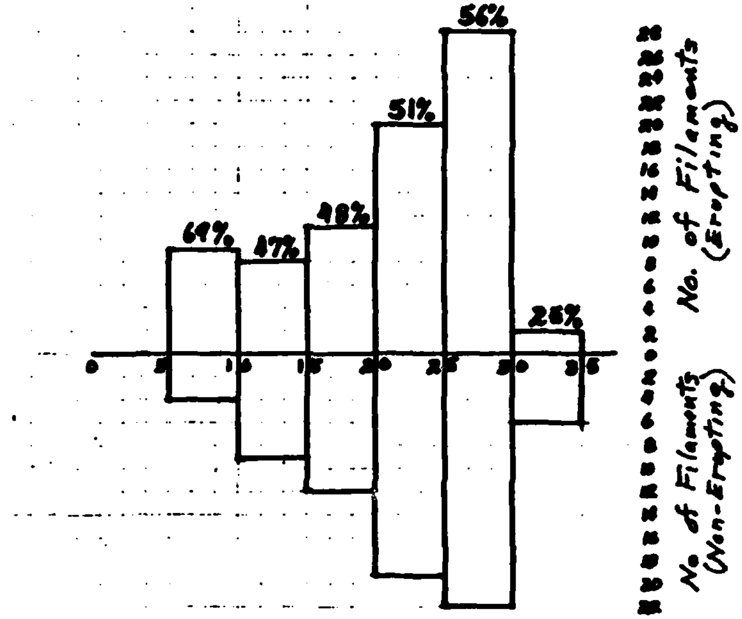
total : 56/117 : 48%

Filaments which erupted within 3 days of the emergence of new flux

Filaments which did not erupt within 3 days of the emergence of new flux

1973 DATA

Distance vs Number of Filaments



Top Bars → Erupted Filaments

Bottom Bars → Filaments Which Did Not Erupt.

78/140 → 56%

Figure 3

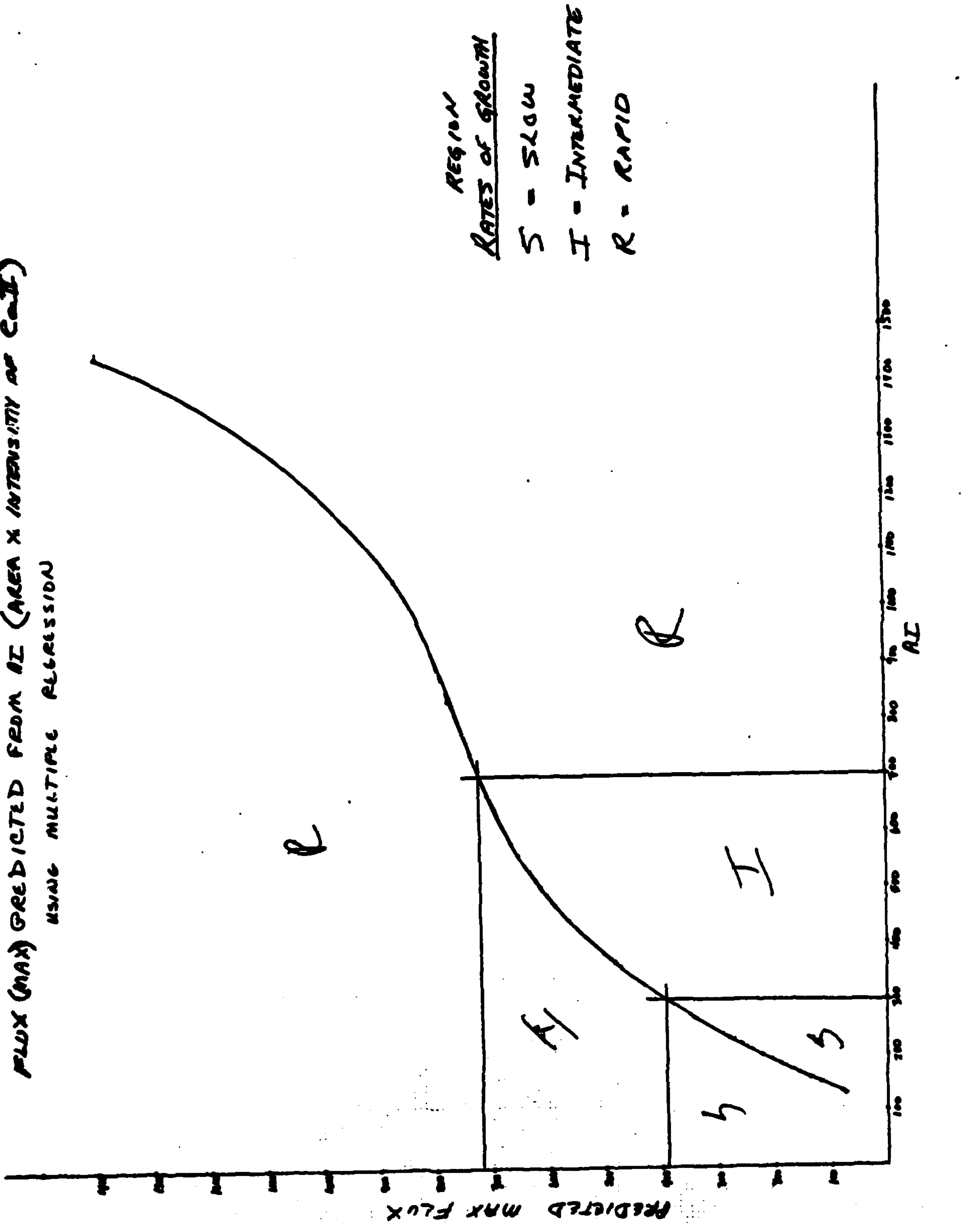

FLUX (MAX) PREDICTED FROM AI (AREA X INTENSITY OF CaII)
USING MULTIPLE REGRESSION
REGION
RATES OF GROWTH
S - SLOW
I - INTERMEDIATE
R - RAPID
PREDICTED MAX FLUX
AI

Figure 4

We sought to find out if the likelihood of eruption was dependent upon its length. For each filament in our 1978-79 data set, the length was measured on a day when it was near the center of the solar disk. The result is shown in Figure 5. This graph shows that shorter filaments are more likely to erupt than longer ones. This might be the situation because short filaments are surrounded by less total flux than long ones supporting our finding that the total flux surrounding a filament is related to probability of eruption. If the flux is the important parameter, rather than the length of the filament, the percentage of eruptions should not appreciably change if the flux is normalized by dividing it by the length of the length of the filaments. Figure 6 is a histogram of the normalized flux vs the number of filaments which did and did not erupt. This graph shows that the relationship remains the same in that the greater the normalized flux surrounding the filament, the less likely the filament is to erupt. Comparing this result for normalized flux with non-normalized flux (Figure 1), no significant differences are apparent.

3.2 Testing for Magnetic Reconnection as a Possible Triggering Mechanism for Filament Eruption

The above factors relating the birth and early development of active regions to the eruption of filaments, causes us to suspect a physical connection between them as already hypothesized by Bruzek (1952). He suggested that the existence of a disturbance, emanating from new active regions propagating with a speed of about 1 Km/sec., could explain the time relationship which he found between the birth of new active regions and the subsequent eruption of quiescent filaments in the neighborhood of the new active regions. Since the publication of many papers showing satellite-borne X-Ray photographs such as from the AS&E experiment on board Skylab (Zombeck et al., 1978), it is now evident that magnetic reconnection occurs between the magnetic fields of new active regions and the surrounding, pre-existing magnetic fields coincident with or very soon after the development of the new regions. If we hypothesize that the pre-existing magnetic fields supports the filament mass, then magnetic reconnections would decrease the amount of field available for filament support. If sufficient supporting field is reconnected to other areas on the sun, the filament would either collapse or erupt. Since filament eruption is frequently observed and filament collapse rarely, if ever, observed, we assume that the role of the magnetic field adjacent to filaments is such as to prevent their eruption as long as the field is sufficiently great.

In the soft x-ray data from the AS&E experiment, we have sought evidence of the existence of magnetic reconnection between new active regions and their neighboring magnetic fields assumed to support filaments in our data sample. We studied the images in the 16mm film published by AS&E of their x-ray images of every 64 sec exposure in the wavelength bands of 2-32A and 44-54A. X-ray loops were seen originating in newly formed active regions and emanating in the

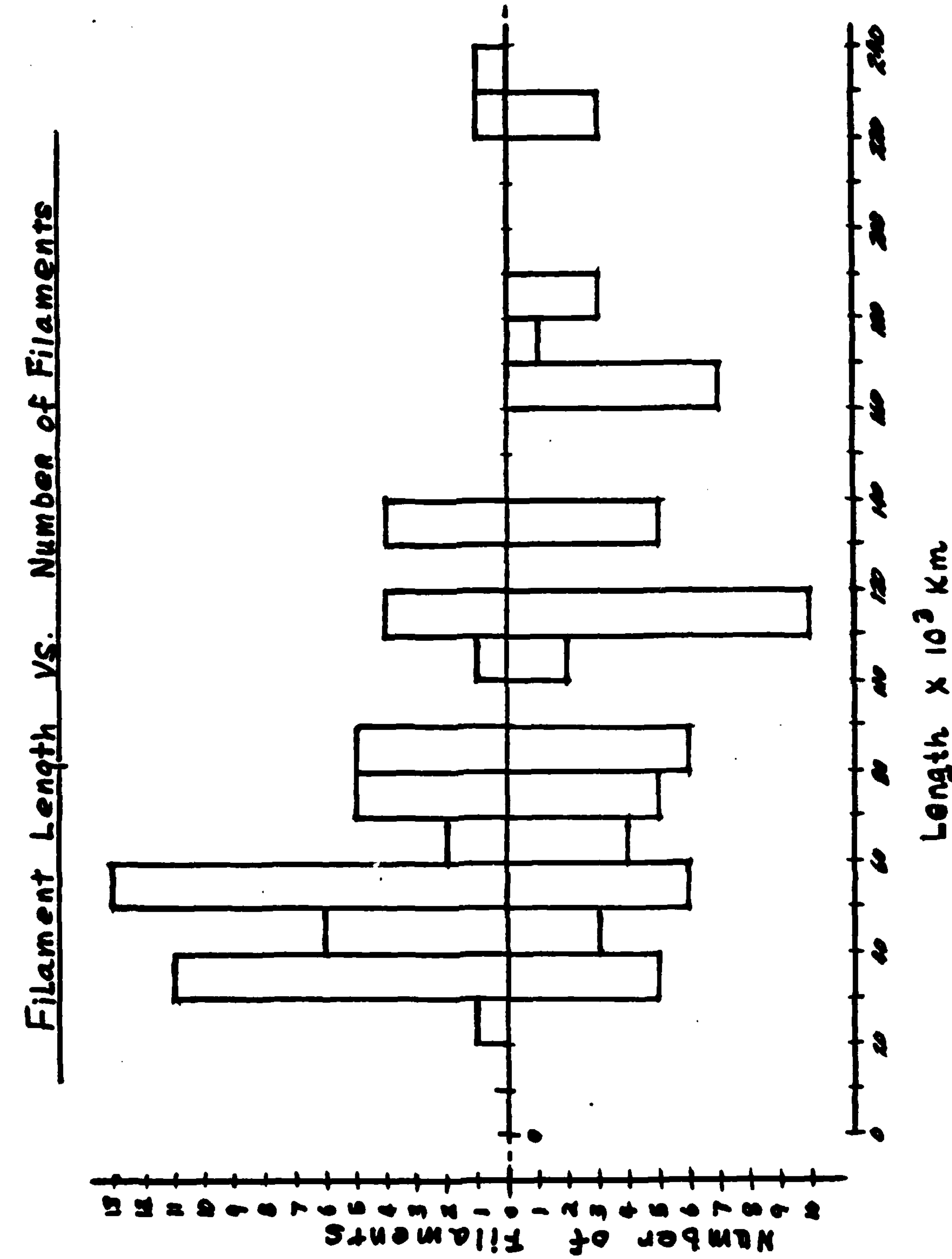
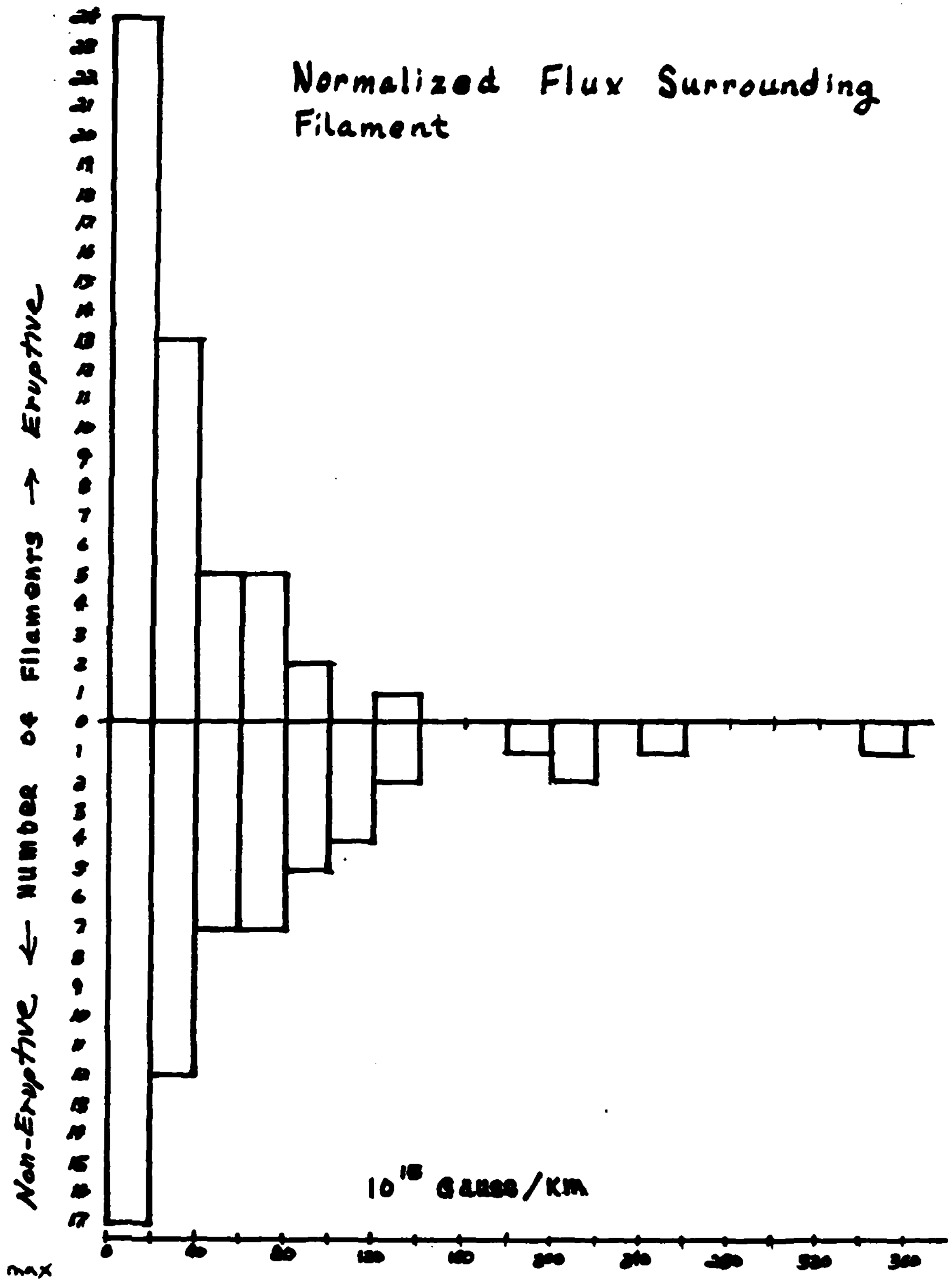

Filament Length vs. Number of Filaments
Length x 10^3 Km
Number of Filaments

Figure 5



Normalized Flux Surrounding Filament
Non-Eruptive ← Number of Filaments → Eruptive
10^{15} Gauss/KM
max

Figure 6

direction of some filaments. However, we also found that most of these loops were probably due to flares occuring in the new regions and were not the magnetic reconnections being sought. Also most of the magnetic fields adjacent to filaments which erupted did not seem to have any x-ray loops connecting to surrounding magnetic fields.

X-ray loops from the above film have been mapped onto Hα synoptic charts (Hanson et al., 1980). Using these charts, we counted the number of filaments which did and did not erupt for three categories: (1) filaments which were crossed by an x-ray loop, (2) filaments at a loop footpoint or within 3 degrees of a loop and (3) filaments which were more than 3 degrees from a loop. 444 filaments were thus studied and the results are shown in Figure 7. From this graph it appears as if a filament has a greater chance of erupting if it is crossed by or is within 3 degrees of an x-ray loop, than if it is more than 3 degrees away from a loop. However, as seen in the ASE film, most of the loops within 3 degrees of a filament did not come from a new region. Therefore, the results of this study are inconclusive and do not provide evidence for the existence of magnetic reconnection between new active regions and adjacent filament supporting magnetic fields.

The absence of evidence of reconnections is not a negative result. Since the fields around filaments that erupt are usually very weak, we think that the exposures on the x-ray film were simply too short to reveal the presence of loops connecting to very weak magnetic fields. In the absence of a negative result, and because of the well-documented evidence that magnetic reconnections apparently do take place, we suggest that magnetic reconnection (or whatever causes it) is the most likely mechanism by which the birth and development of new active regions could trigger the eruption of neighboring quiescent filaments.

3.3 Relative Orientation of the Magnetic Polarities of the New Regions and the Magnetic Fields Adjacent to Filaments

If the eruption of filaments is triggerred by magnetic reconnection between the magnetic fields of new active regions with adjacent fields that provide for the containment of filaments (and prevent their eruption), then the relative orientations of both of these magnetic fields may yield conditions that are more or less favorable for the eruption of the filaments.

The relative orientations of the new and adjacent old fields were divided into 3 categories considered to be (1) favorable, (2) semi-favorable, and (3) unfavorable for magnetic reconnection to occur between the new region fields and the fields adjacent to the filaments. The 3 categories are illustrated in Figure 8. In the favorable category, the polarity of the new region is opposite the polarity of field adjacent to the filament and faces the direction of the filament. In the unfavorable category, the polarity of the new region that is the same as the polarity of the adjacent filament field and faces the direction of the filament. The semi-favorable category,

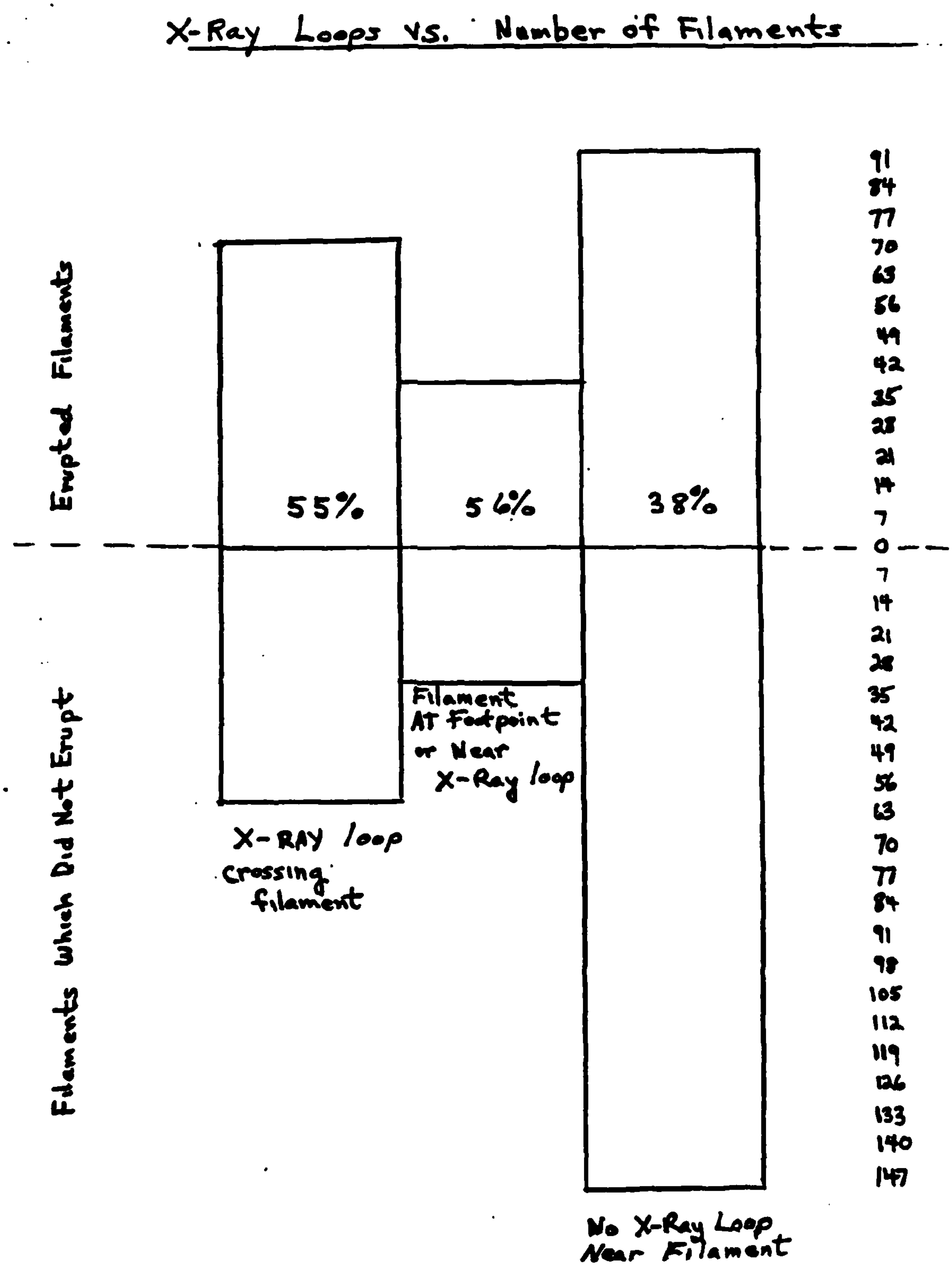

X-Ray Loops vs. Number of Filaments
Erupted Filaments
Filaments Which Did Not Erupt
55%
56%
38%
Filament At Footpoint or Near X-Ray loop
X-RAY loop crossing filament
No X-Ray Loop Near Filament
91
84
77
70
63
56
49
42
35
28
21
14
7
0
7
14
21
28
35
42
49
56
63
70
77
84
91
98
105
112
119
126
133
140
147

Figure 7

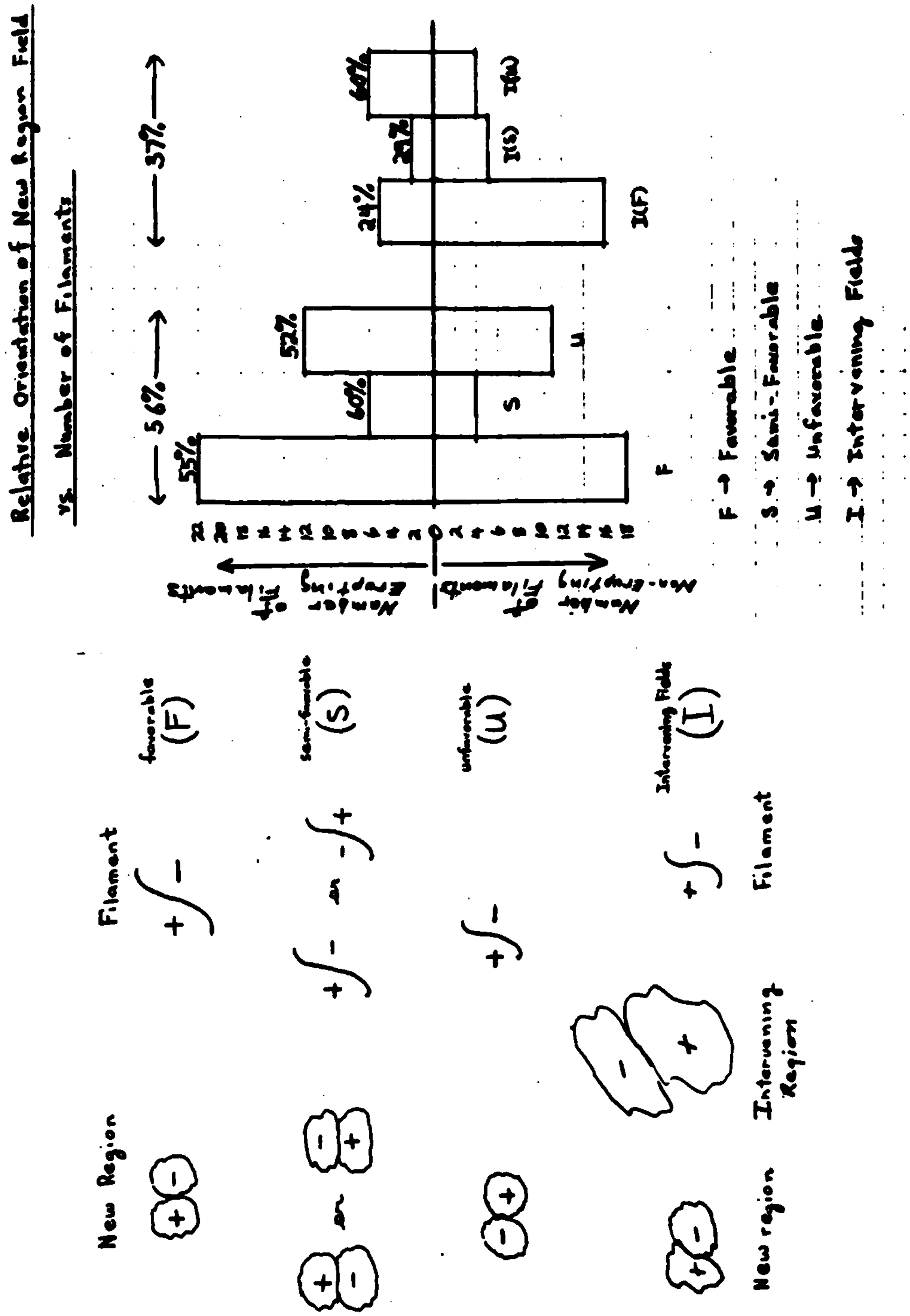

1978-79 DATA
Relative Orientation of New Region Field
vs. Number of Filaments
Number of Filaments Erupting
Number of Filaments Non-Erupting
56%
37%
F → Favorable
S → Semi-Favorable
U → Unfavorable
I → Intervening Fields
New Region
Filament
favorable (F)
semi-favorable (S)
unfavorable (U)
Intervening Fields (I)
Intervening Region
New region

Figure 8

both polarities are equidistant from the filament.

Another factor which might appreciably affect the possibility of magnetic reconnection occurring between new active regions and fields adjacent to quiescent filaments is the presence of an intervening field in addition to the field adjacent to the filament. In such a case we would first expect reconnection to occur with the intervening field and secondarily or not at all with the field surrounding the filament. To test for this possibility, we additionally divided the data as categorized above into groups according the the presence or absence of of intervening fields.

The graph in Figure 8 shows the grouping of the data by relative orientation and the presence or absence of intervening magnetic fields versus the number ot filaments which did and did not erupt. The histograms include 113 cases in the 1978-79 data set. They show that the liklihood of eruption is about the same for each orientation category. Hence, we conclude that the relative orientations as defined here are not relevant to the erupting filament mechanism. However, the presence the intervening fields may be an important factor. About 20 percent fewer filaments erupted when intervening fields were present.

The absence of evidence that magnetic orientation is important in whether a new region can trigger a filament eruption cannot be be considered as negative evidence that magnetic reconnection does not take place. It may be that, as long as a new region is embedded in the extensive but weak magnetic fields associated with quiescent filaments, any orientation is equally effective in destroying the containment of a filament by the reconnection of its supporting magnetic field to a new active region.

3.4 Longitude Comparison of New Regions and Filament Eruptions

If active regions were not randomly distributed on the sun but instead preferentially occurred near unstable neutral lines, one would not need to hypothesize the existence of magnetic reconnections to explain the relationships between the eruption of filaments and the growth of new active regions. An initial test of this possibility is to see if there could be any preferred longitudes for both active centers and erupting filaments.

The clustering of active regions into well defined latitude zones in each hemisphere is well known (Carrington, 1858; Maunder, 1922; Greenwich Royal Observatory, 1956; Becker, 1954; Bell, 1960). The relationship has been further documented by region age by Harvey, Harvey, and Martin (1975). Conflicting answers have been found on the question ot whether active regions cluster in longitude. Harvey, Harvey and Martin (1975) found no tendency for isolated new regions of any age group to cluster in longitude although Weart (1972) and Martin et al. (1982) found that new active regions have a strong tendency to occur in existing active regions, confirming the current widely held

view that "active longitudes" do exist.

To test our data samples for a possible clustering in longitude, the number of filament eruption and new regions were counted in longitude intervals of thirty degrees over six solar rotations (rotations No. 1602-1607) from 1 June 1973 to 30 October 1973. These measurements were obtained using Hα synoptic charts on which were drawn all eruptive filaments (found by comparing daily neutral line maps and studying hydrogen alpha films) and emerging flux regions (found from the Solar Geophysical Data Reports and Mt. Wilson Magnetograms). In all 74 new regions and 165 filament eruptions were included in this study.

Figures 9a thru 9f show plots of the number of new regions and erupting filaments versus longitude. Comparison of the different rotations seems to show that the new active regions tend to occur randomly with respect to longitude. The same appears to be true for filament eruptions. There is no apparent correlation between new regions and erupting filaments as one might suspect from Fig. 1-3. However, other factors need to be considered. Not all erupting filaments are triggered by the birth of new active regions. Only the special conditions of low total magnetic field and/or the rapid growth of new regions in the vicinity of a quiescent filament have found to be related to filament eruption. These special conditions apply to a fraction of the data. Also, most quiescent filaments, which erupt within thirty heliographic degrees of a new region, erupt within the first three days of the new region's formation. Comparing rotations does not take this into account. *All new regions* and eruptions represented in the graphs can take place at any time within a period of half a solar rotation or about fourteen days.

3.5 Distance Between New Regions and Neutral Lines

Another question about the relationship found between filament eruptions and the growth of new active regions, is whether it is more meaningful to measure the distance to the center of the filament as done for the data in Figures 3A to 3B or the distance to the nearest point on the neutral line over which the filament resides. Fig. 10 in comparison with Fig. 3A and 3B shows that it makes very little difference which distance is measured except for regions very close to the neutral line. Fig. 10 gives the distance of the new regions from the nearest point on the closest neutral for the filaments that did and did not erupt. It shows that there is a higher liklihood of eruption (65%) when a new active center is within five heliographic degrees of the same neutral line which the filament is on. The percentage of eruptions decreases substantially when a new center is more tha five degrees from the filament neutral line (to about 40%).

Fig. 10 also shows that a large number of new regions form within five degres of the filament neutral line. To see if this result is the same for neutral lines in general, the number of new regions versus the distance of the new active regions to the nearest neutral

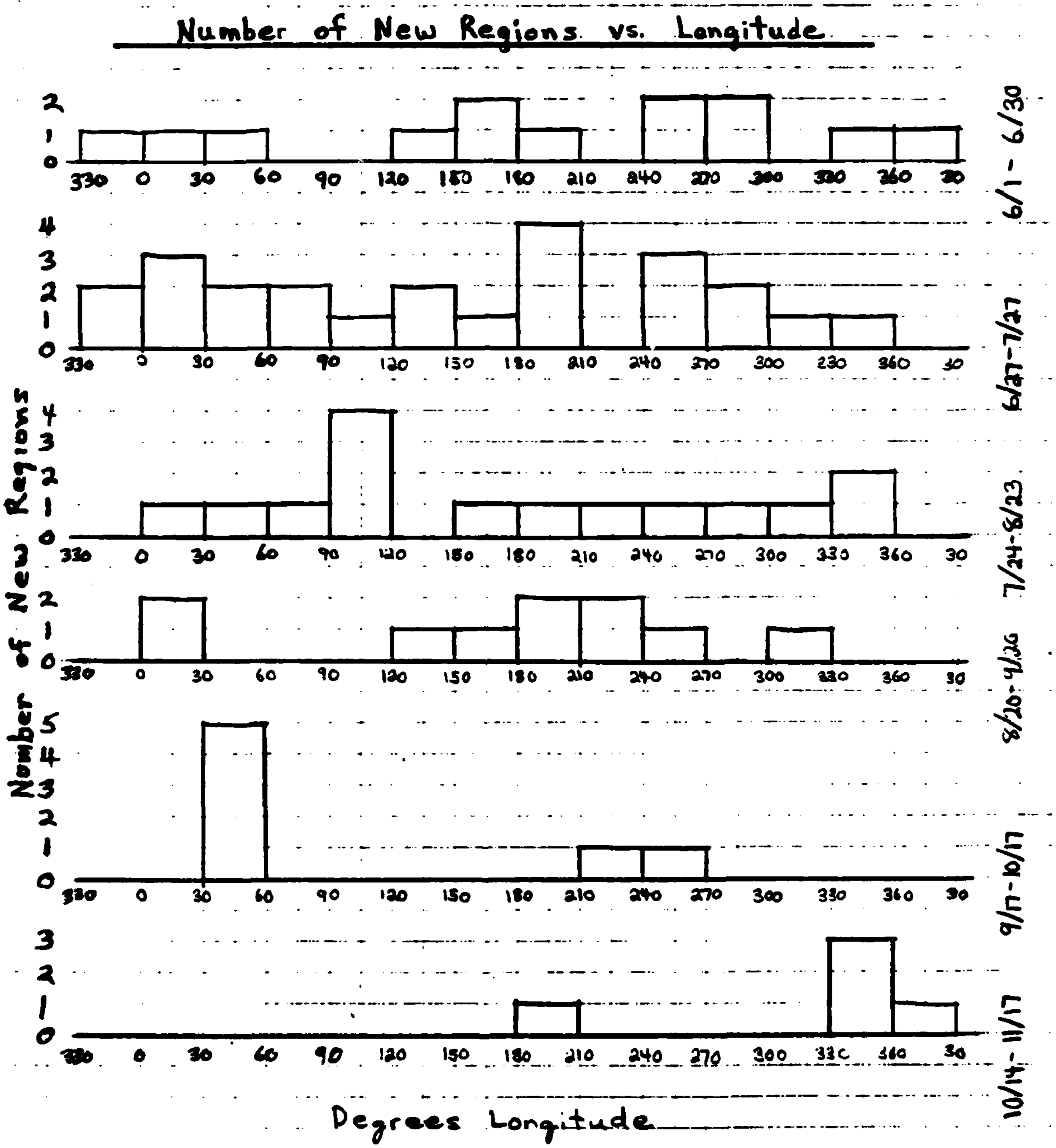

Number of New Regions vs. Longitude
6/1 - 6/30
6/27-7/27
7/24-8/23
8/20-9/26
9/17-10/17
10/14-11/17
Number of New Regions
Degrees Longitude

Figure 9a

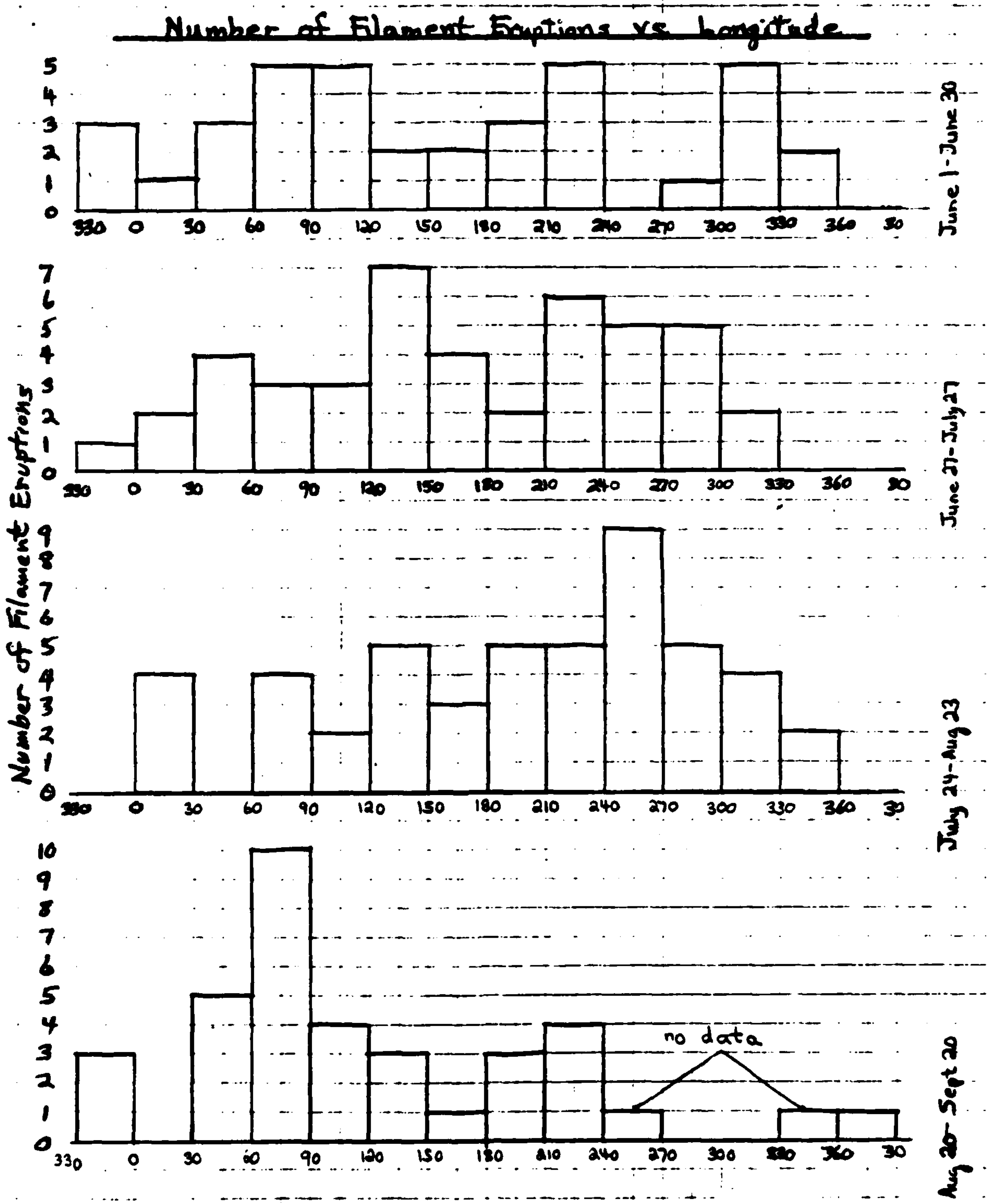
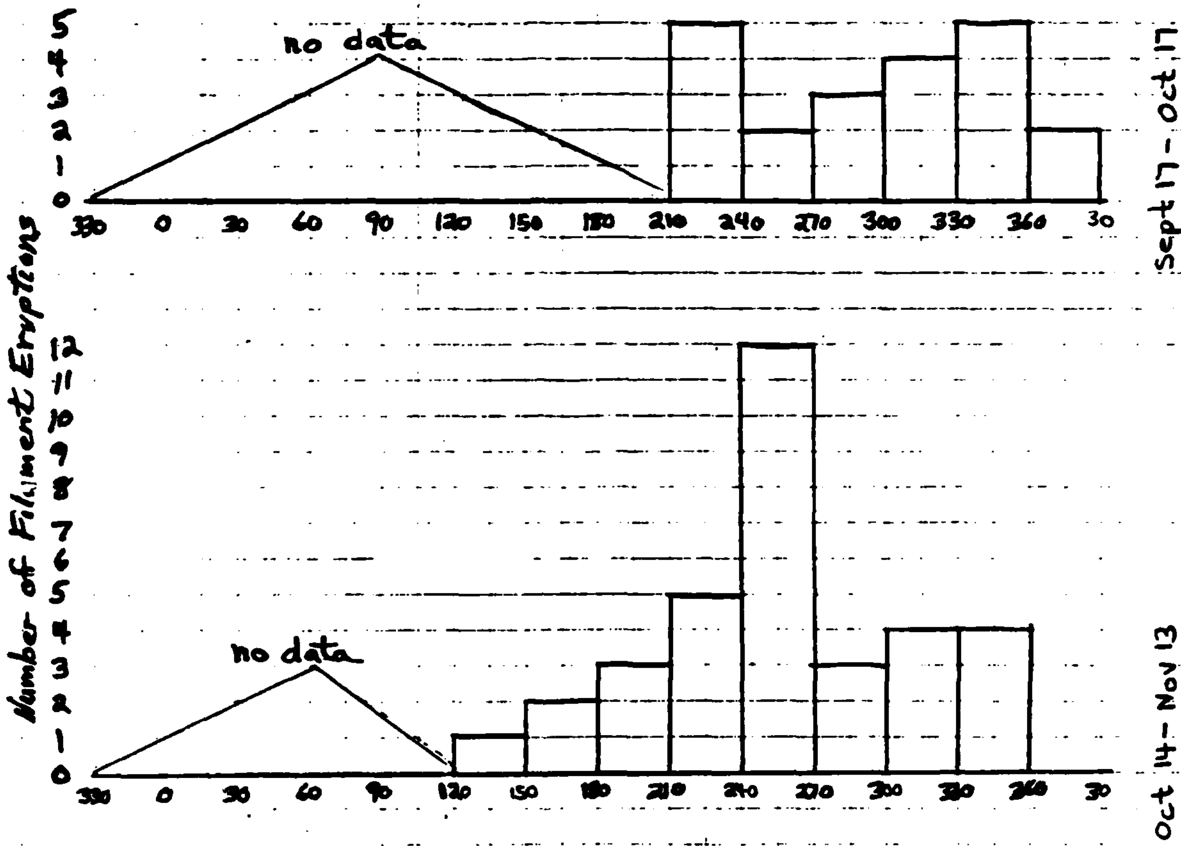

Number of Filament Eruptions vs Longitude
Number of Filament Eruptions
June 1-June 30
June 27-July 27
July 24-Aug 23
Aug 20-Sept 20
no data
330
0
30
60
90
120
150
180
210
240
270
300
330
360
30

Figure 9b



<u>Missing Dates</u>

June 16, 17, 19, 22

August 26, 27, 28, 29, 30, 31

September 28, 29, 30

October 1-14, 29, 30, 31

Figure 9c

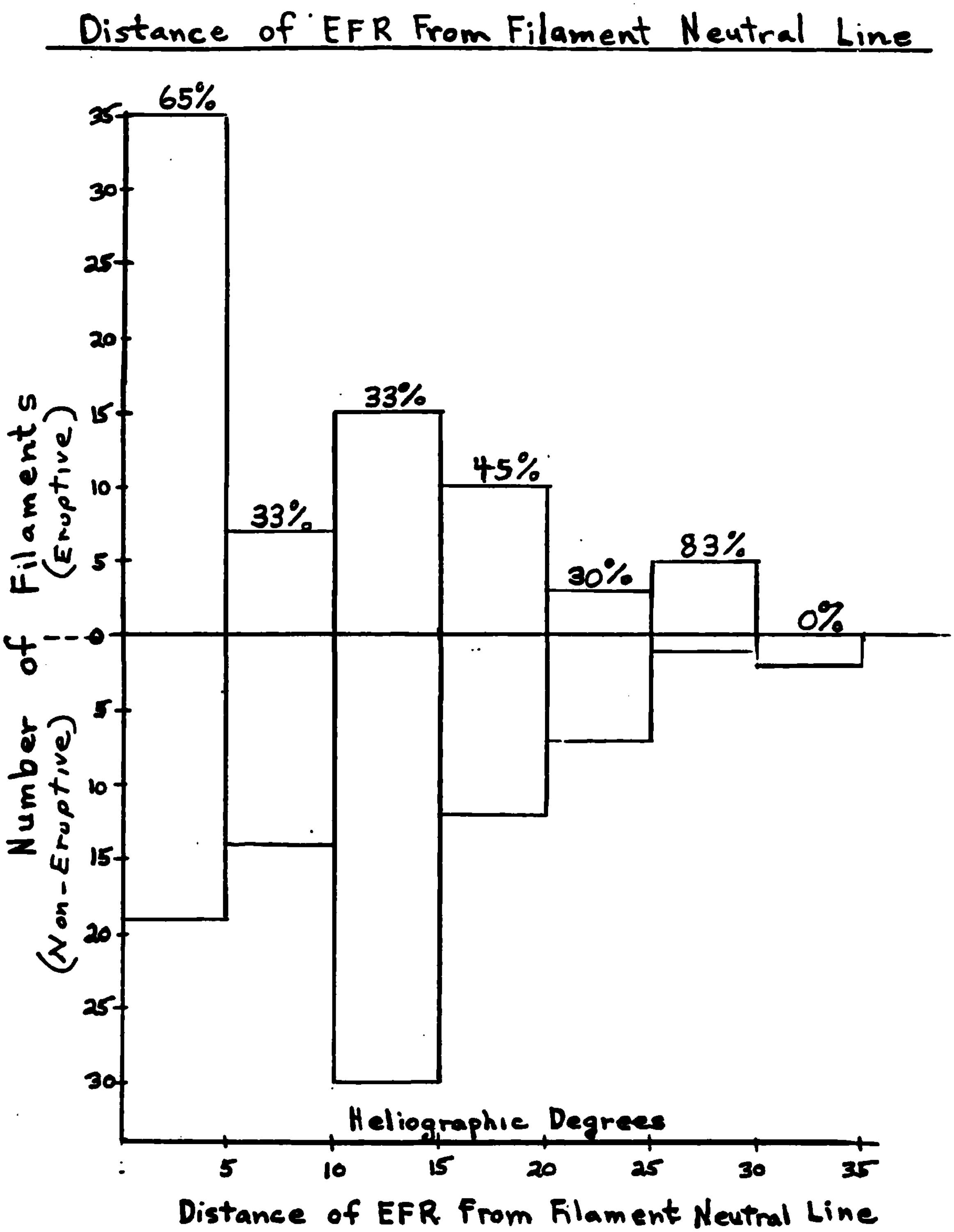

Distance of EFR From Filament Neutral Line
65%
33%
33%
45%
30%
83%
0%
35
30
25
20
15
10
5
0
5
10
15
20
25
30
Number of Filaments
(Eruptive)
(Non-Eruptive)
Heliographic Degrees
5
10
15
20
25
30
35
Distance of EFR From Filament Neutral Line

Figure 10

line, whether or not there was a filament on it, was plotted. The result is shown in Figure 11. It appears as if new regions tend to cluster around neutral lines in general. To determine whether this relationship varies with the rate of growth of the new regions, in Figure 12, a similar type of graph to Figure 11 are shown with the active regions separated into three groups according to their rates of growth as rapid, intermediate, and slow. Figure 12 shows that rapidly growing regions seem to form closer to the neutral lines than either intermediate or slow and the intermediate regions tend to be closer to the neutral lines than the slow regions.

To test the statistical significance of this apparent relationship, the study was repeated after randomly redistributing the regions in longitude. The consequence of this redistribution is shown in Figure 13 and 14. The randomized data tends to cluster 5-6 degrees from the neutral line for all three groups of regions by rate of growth but otherwise the randomized data appears to be distributed similar to the real data. The chi-square statistical test was applied to see if there is any significant difference between the real data and the randomized data. There was no significant difference at the 5 percent level. We suspect that the tendency for the real data to be clustered more closely to the neutral line is a systematic human error in the determination of the neutral lines. Every new region develops a new neutral line and the person constructing the synoptic chart from Ha images and magnetograms has a tendency therefore to draw the neutral line thru the new regions thereby simplifying the task.

To further test the validity of the above results, a similar analyses was done for all new regions observed from July thru September 1980 since the data from which the neutral line maps are constructed is of higher quality during the 1973 interval. Also, in addition to using the neutral line maps from Boulder, we independently made another set of neutral line maps from Kitt Peak magnetograms. There are substantial variations between the Boulder maps and our maps showing that there is a subjective element in the neutral line determinations. When the 1980 data was randomized, however, it is quite clear that there is no significant difference between the the real data and the randomized data. Confirming this, the Chi-square test showed no significant difference at the 5 percent level.

We conclude that most active regions, that form outside of pre-existing active regions, do not have a significant tendency to cluster around pre-existing neutral lines. Thus, no evidence was found that any factor in the distribution of either active regions or filaments which would change our preceding conclusion that new active regions can act as the trigger for erupting filaments in their vicinity.

4.0 TESTS OF PHYSICAL SIGNIFICANCE

The Chi Square test was applied to determine the degree of statistical significance of the most important parameters that were found to be related to the eruption of quiescent filaments. The rate of growth of

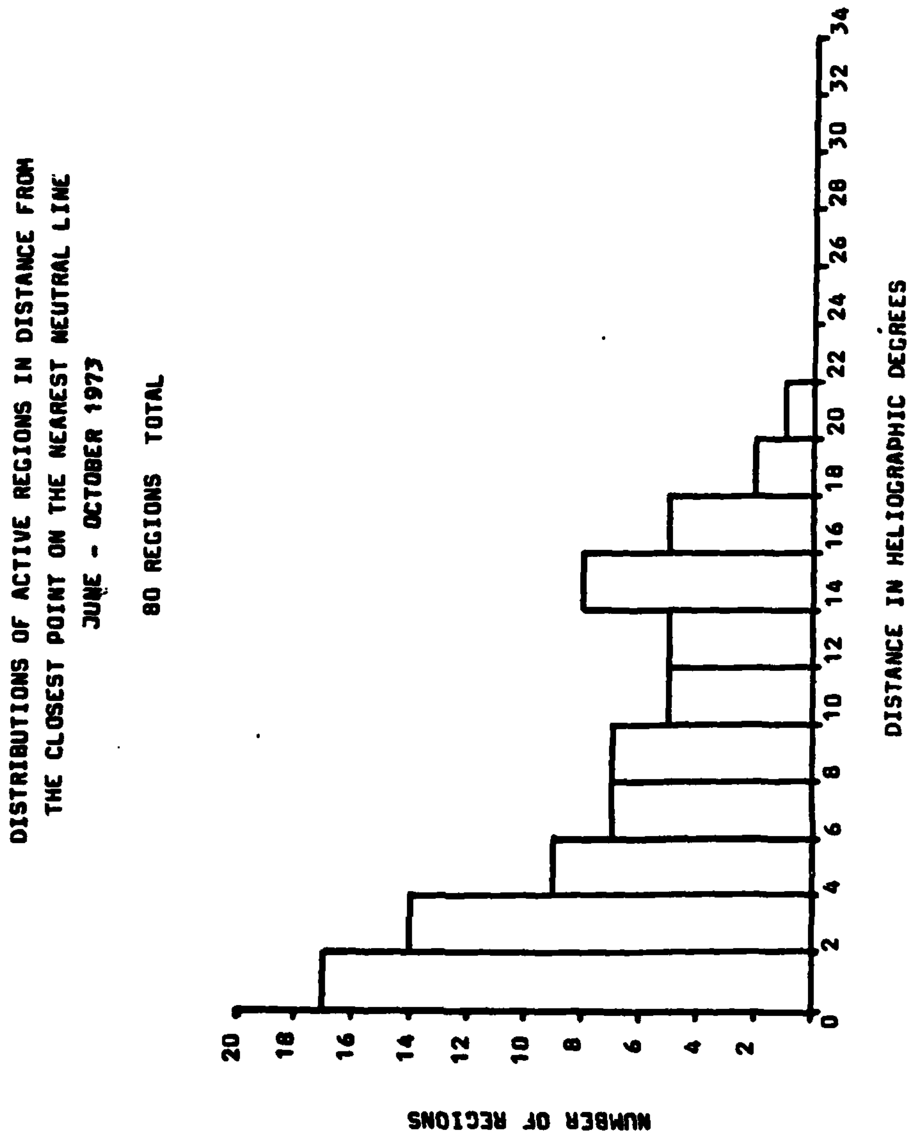

DISTRIBUTIONS OF ACTIVE REGIONS IN DISTANCE FROM
THE CLOSEST POINT ON THE NEAREST NEUTRAL LINE
JUNE - OCTOBER 1973
80 REGIONS TOTAL
NUMBER OF REGIONS
DISTANCE IN HELIOGRAPHIC DEGREES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34

Figure 11

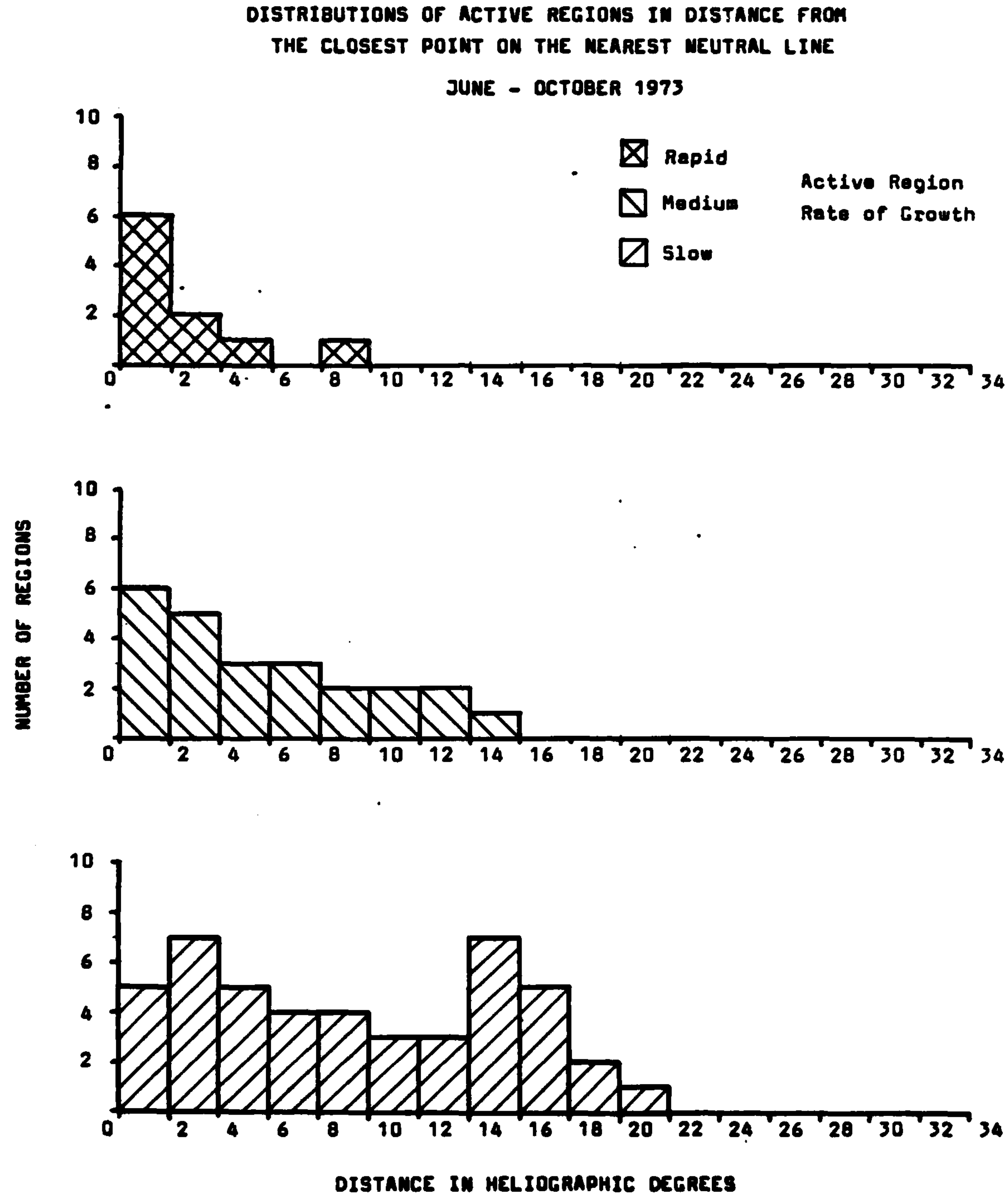

DISTRIBUTIONS OF ACTIVE REGIONS IN DISTANCE FROM
THE CLOSEST POINT ON THE NEAREST NEUTRAL LINE
JUNE - OCTOBER 1973
Rapid
Medium
Slow
Active Region
Rate of Growth
NUMBER OF REGIONS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
DISTANCE IN HELIOGRAPHIC DEGREES

Figure 12

ACTIVE REGIONS RANDOMLY REDISTRIBUTED IN LONGITUDE AND SHOWN AS A FUNCTION OF DISTANCE FROM THE CLOSEST POINT ON THE NEAREST NEUTRAL LINE

JUNE - OCTOBER 1973

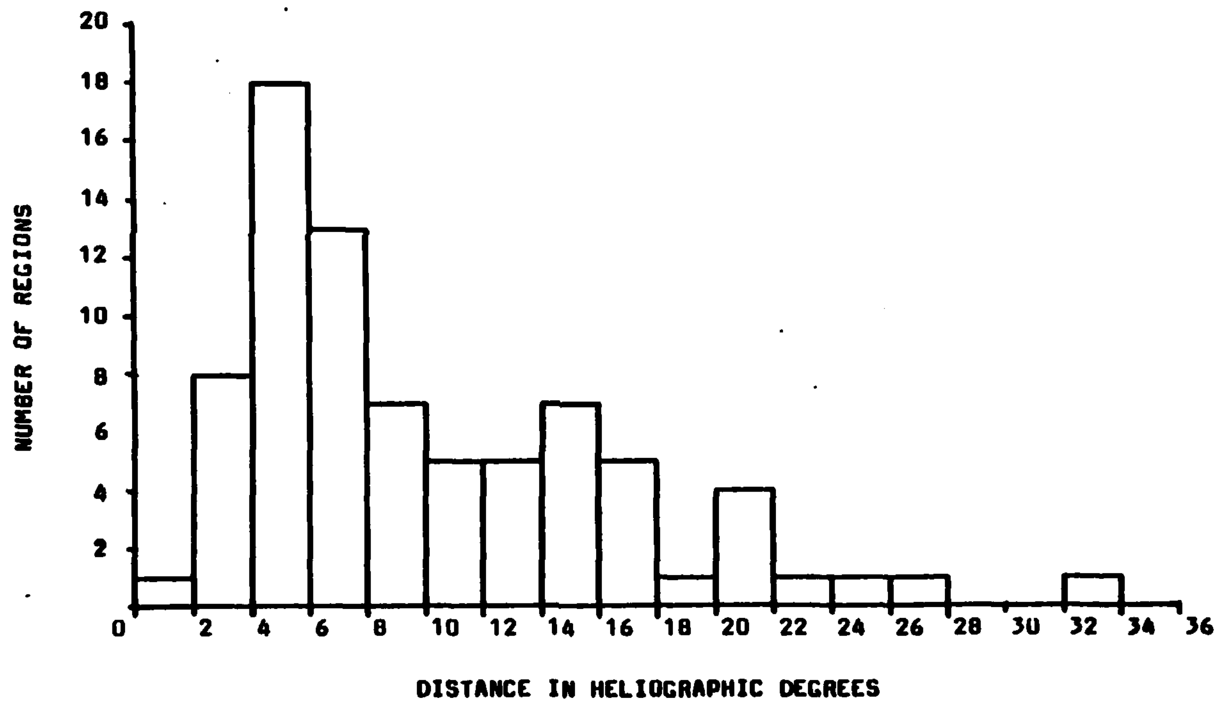


Figure 13

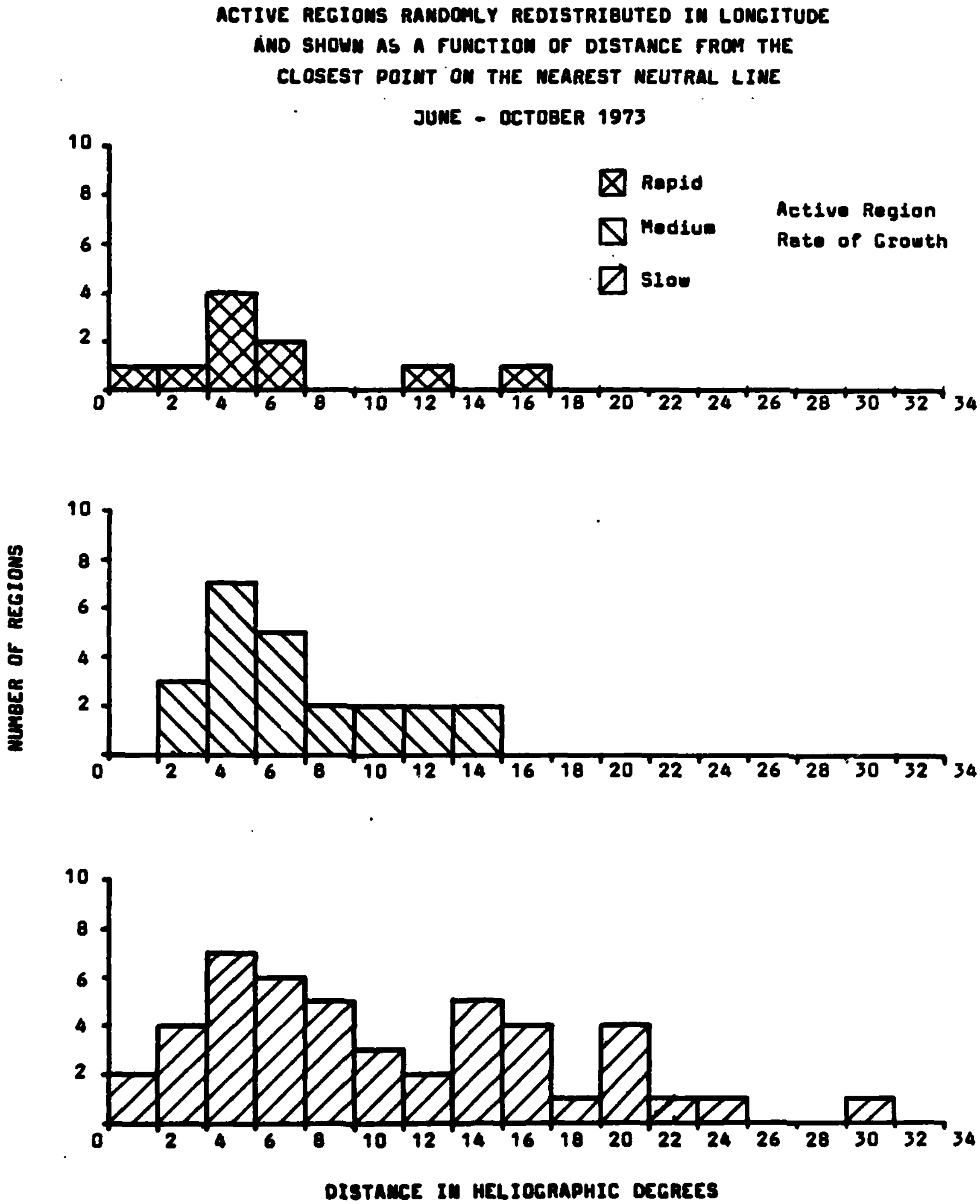

ACTIVE REGIONS RANDOMLY REDISTRIBUTED IN LONGITUDE
AND SHOWN AS A FUNCTION OF DISTANCE FROM THE
CLOSEST POINT ON THE NEAREST NEUTRAL LINE
JUNE - OCTOBER 1973
Rapid
Medium
Slow
Active Region
Rate of Growth
NUMBER OF REGIONS
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
DISTANCE IN HELIOGRAPHIC DEGREES

Figure 14

new active centers and the flux of magnetic field potentially involved in supporting the filament were both found to be significant at the .001 level. However, the distance between the filaments and the new regions was not significant at the .05 level. This lack of a significant relationship for the distance parameter could be taken at face value or it could indicate that the distances considered in this study were not sufficiently large, or it could mean that the distances should be weighted in relation to the size of the filaments or the extent of the flux assumed to be supporting the filaments.

5.0 DEVELOPMENT OF A FORMULA FOR FORECASTING THE ERUPTION OF SOME QUIESCENT FILAMENTS

Multiple regression analyses were applied to arrive at a formula for forecasting the eruption of quiescent filaments in which a relative weighting is given to the correlated parameters. Since it was found that the distance between the filaments and the new regions did not significantly correlate (at the .05 level) with the percent of eruptions, this parameter was omitted. It was found that the following equation with 3 significant terms adequately represented the percent of eruptions that could be expected knowing the rate of growth of the new regions and the flux around the filaments.

$$P = 55 + 14K_{f1} + 4K_{f2} - 18K_{f3}$$

P is the probability of the eruption of a quiescent filament and in the
table below:

K_{f1} = coded value for the linear contribution of total flux around a filament

K_{f2} = coded value for the quadratic contribution of $(\text{total flux})^2$

K_{f3} = coded value for the linear contribution of the rate of growth of new active regions

Table 1.

Magnetic Flux X 10^{19} Maxwells

coded value	0-249	250-399	400+
K_{f1}	1	0	-1
K_{f2}	1	-2	1
K_{f3}	1	0	-1
	0-199	200-599	600+

Rate of Growth of New Region X 10^{19} Maxwells/Day

The 80 percent confidence limits for the forecasts made using this formula are ± 14 percent and the 95 percent confidence limits are ± 23 percent.

6.0 APPLICATION OF THE FORECASTING FORMULA

The formula is based on significant groupings of the data into 3 bins with respect to the total flux of the magnetic fields adjacent to the filaments and 3 bins with respect to the rate of growth of the new regions. We found little evidence in the data to suggest that finer divisions of flux or rate of growth would be statistically significant. Additionally, basing the forecasting formula on the groupings has the advantage that the formula can be effectively utilized with either estimates or actual measures of these parameters. In either circumstance, one can simplify the use of the forecasting formula by employing the table in Figure 15. In Figure 15, the 3 groupings of magnetic flux are given as low, medium and high and the 3 groupings of region rate of growth as slow, medium, or rapid corresponding to the values in Table 1. The values in the table are the probability of eruption of quiescent filaments for the 9 possible combinations magnetic flux and rate of new region growth.

Because of the area and intensity of CaII plage and Ha plage correlates well with total magnetic flux, the formula or its reduced format in the table in Figure 15, can be applied using any telescope equipped with a narrow band Ha or CaII filter. Hence this formula could be employed at most solar observatories in the U.S. Additionally, very few observatories have magnetographs that yield maps or images in real time. Hence the alternative of using Ha or CaII images in making the forecasts is very practical at the present time.

PROBABILITY OF ERUPTION

TOTAL FLUX AROUND FILAMENTS \ RATE OF GROWTH OF NEW REGIONS	RAPID	MED.	SLOW
LOW	92%	74%	56%
MED	77%	59%	41%
HIGH	64%	46%	28%

Figure 15

7.0 REFERENCES

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D. PUBLICATIONS

D.1 Papers Published

(a) "Terrestrial Observations Preceding the Flare on 5 September 1973, 1826 UT", Van Hoven et al., Solar Flare Workshop Monograph, (1979).

(b) "Mechanical Energy Output of the 5 September 1973, 1826 UT Flare", Cheng, C.C., Dulk, G.A., Edberg, S.J., Martin, S.F., McKenna-Lawlor, S., McLean, D.J., and Webb, D.F., Solar Flare Workshop Monograph, Appendix B (1979).

(c) "Study of the Post-Flare Loops on 29 July 1973, III Dynamics of the Ha Loops", Solar Phys. 64, 165 (1979).

(d) "Study of the Post-Flare Loops on 29 July 1973, IV Revision of T and n Values and Comparison with the Flare on 21 May 1980", Svestka, Z., Dodson-Prince, H.W., Martin, S.F., Mohler, O.C., Moore, R.L., Nolte, J.T., and Petrasso, R.D.: 1982, Solar Phys. 78, 271.

(e) "Forecasting Solar Flares Based on Magnetic Field Configurations", Harvey, K.L. and Martin, S.F., Proceedings of the Solar Terrestrial Predictions Workshop (ed.) R. Donnelly, Vol. III, C-30 (1980).

(f) "Preflare Conditions, Changes, and Events" (a review), Martin, S.F., Solar Phys. 68, 217 (1980).

(g) "Dynamics of Flare Sprays", Tandberg-Hanssen, E., Martin, S.F., and Hansen, R.T., Solar Phys. 65, 357 (1980).

(h) "Particle Acceleration in the Process of Eruptive Opening and Reconnection of Magnetic Fields", Svestka, Z., Martin, S.F. and Kopp, R.A., Solar and Interplanetary Dynamics, IAU Symp. 91, (ed.) E. Tandberg-Hanssen and M. Dryer, p. 217 (1980).

D.2 Papers to be Published

(a) "A Formula for Forecasting the Eruption of Some Quiescent Filaments" Hermans, L. and Martin, S.F. (to be submitted to Solar Physics).

E. PROFESSIONAL PERSONNEL ASSOCIATED WITH THE PROJECT

1. Sara F. Martin (Principal Investigator), Adjunct Professor in Physics and Astronomy, California State University, Northridge

2. Earle B. Mayfield (Co-Investigator, July 1976-30 Sep. 1978) Adjunct Professor, CSUN; Staff Scientist, Aerospace Corporation

3. Karen L. Harvey (Consultant), Visiting Solar Astronomer, Kitt Peak National Observatory and Staff Scientist, Solar Physics Research Corporation, Tucson, Arizona

4. Roger A. Kopp (Co-Investigator), Los Alamos Scientific Laboratories of the University of California, Los Alamos, New Mexico

F. INTERACTIONS

F.1 Papers Presented at Formal Scientific Meetings

1. "Inferences from the Motions of Eruptive Prominences", Martin, S.F., 150th American Astronomical Society, Atlanta, Georgia, 12-15 June 1977

2. "The Moving Emission Front Accompanying the Flare of 5 September 1973, 1826 UT", Martin, S.F., American Astronomical Society Meeting, Madison, Wisconsin, 26-29 June 1978

3. Energy Analyses of the Mass Ejecta Accompanying the Flare of 5 September 1973, 1826 UT", Edberg, S.J., Martin, S.F., and Webb, D.F., Presented at the Workshop on Flare Research and the Solar Maxium Mission sponsored by the Solar Physics Division of the AAS, Ann Arbor, Michigan, 14-16 Nov. 1978

4. "An Interpretation of Emission Halos around Flares", Glackin, D. and Martin, S.F., Workshop on Solar Flares and the Solar Maximum Mission, 14-16 Nov. 1978

5. "Particle Acceleration in the Process of Eruptive Opening and Reconnection of Magnetic Fields", Z. Svestka, S.F. Martin and R.A. Kopp, IAU Symp. 91, Boston, Mass., 26-31 Aug. 1979

6. "An Experiment in Predicting the Eruption of Filaments", Martin, S.F., Edberg, S.J., Hermans, L.M., and Dunn, J.M. 155th Meting of the American Astronomical Society, San Francisco, California, 13-18 Jan. 1980

7. On the Relationship Between the Eruption of Quiescent Filaments and the Development of New Active Centers" Hermans, L.M. and Martin, S.F., 156th Meeting of the American Astronomical Society, College Park, Maryland, 15-18 June 1980

8. "An Attempt to Identify Flare Precursor Mass Motions in Real Time", Dunn, J.M. and Martin, S.F., Meeting of the Solar Physics Division of the AAS, Taos, New Mexico, 7-10 Jan. 1981

9. "Factors Related to the Eruption of Quiescent Filaments", Hermans, L.M., Martin, S.F., and Marquette, W.H., Meeting of the Solar Physics Division of the AAS, Taos, New Mexico, 7-10 Jan. 1981

10. "X-Ray Observations of Two Different Systems of Post-Flare Loops", Svestka, Z., Dodson-Prince, H.W., Mohler, O.C., Martin, S.F., Moore, R.L., Nolte, J.T., and Petrasso, R.D., 158th Meeting of the American Astronomical Society, Calgary, Alberta, 28 June - 1 July 1981

11. "A Formula for Forecasting the Eruption of Quiescent Filaments" Martin, S.F. and Lawrence, G., American Astronomical Society Meeting, Boulder, Colorado, 10-13 Jan. 1982

F.3 Other Formal Scientific Meetings Attended by Principal Investgator

1. Workshops on Solar Flares Sponsored by NASA, Boulder, Colorado, a series of 4 meetings during FY 1977-78

2. US-Indo Workshop on Solar-Terrestrial Physics, Udaipur, India, 16-20 June 1979

3. The 1st SMM Workshop, University of Virginia, Charlottesville, Virginia, 30 April - 2 May 1980

4. SERF Workshop, Stanford University, Stanford, California, 11- 14 August 1980

E.4 Informal Scientific Meetings Attended and Talks Given

(a) California Solar Neighborhood Meetings:
University Of California, Riverside, Feb. 1978
Naval Radio Observatory, La Posta, May 1978
Mt. Wilson Observatory, Sep. 1978
University of California, Los Angeles, Dec. 1978
University of California, San Diego at La Jolla, Mar. 1979
Big Bear Solar Observatory, Big Bear City, July 1979
Big Bear Solar Observatory, Big Bear City, Aug. 1981

(b) "New Active Center Trigger the Eruption of Some Quiescent Filaments", S.F. Martin and L.M. Hermans, California Solar Neighborhood Meeting, California State University, Northridge, 29 Feb. 1980

(c) "Techniques Employed in Making Long Term (1-3 Day) and Short Term (24 Hr.) Predictions of Erupting filaments and Attendant Flares at San Fernando Observatory", S.F. Martin, L.M. Hermans and J.M. Dunn, California solar Neighborhood Meeting, Big Bear Solar Observatory, Big Bear City, 29 Aug. 1980

(d) "Results of the 1980 Experiment in Forecasting the Eruption of

Quiescent Filaments at the San Fernando Observatory", S.F. Martin, Meeting of the HAO Coronagraph/Polarimeter Experimenters and Collaborators, Boulder, Colorado, October 1980

(e) "Forecasting the Eruption of Quiescent Filaments in the Vicinity of New Active Regions" S.F. Martin, Invited Talk to the personnel of the Solar Forecasting Center, Environmental Services, NOAA, Boulder Colorado, Jan. 1982

FILM

5-8